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Title:

Highly efficient evaporation in refrigerating installations with the correspondingly necessary method for obtaining highly stable conditions with minimal and/or desired temperature differences of the media to be cooled in relation to the evaporation temperature.

Technical field:

Systems producing cold conditions in cooling and freezing installations, refrigeration, refrigerating machines for cooling and heating operation, refrigerating installations, refrigerating units, heat pumps, air-conditioning systems and so on.

Prior art:

Known forms of refrigeration are, firstly, dry expansion operation, in which the refrigerant undergoes a pressure reduction via an injection valve and is transformed from the liquid state into a liquid/vapor mixture to evaporate completely in the evaporator, to then leave the evaporator with slightly superheated vapor and thus cool down a second medium by heat absorption, and, secondly, thermosyphon operation, in which the refrigerant is fed via an equalizing and separating vessel to the evaporator in liquid form either by means of gravity or with the aid of a pump and where it is quite possible for the vapor still to contain liquid fractions at the evaporator outlet, and so there is generally no superheating of the refrigerant at the evaporator outlet.

Under practical conditions, all these systems suffer from more or less serious disadvantages, which we eliminate by our invention, and consequently achieve considerable energy and cost savings.

Dry expansion systems have the advantage of a simple type of construction and small refrigerant contents.

The evaporator efficiency is substantially influenced by least possible evaporator superheating.

For the condenser, however, this is disadvantageous, and its requires correspondingly high superheating (improvement in volumetric efficiency, lubrication, etc.).

The point where these two requirements intersect (optimal superheating for the evaporator and condenser, which are conversely optimal) gives the maximum system characteristic (most efficient operation).

Our invention succeeds for the first time in breaking through this dependence between minimal superheating for the evaporator and great superheating for the condenser.

This achieves the effect of operating the process for a given refrigerating output Qo with the smallest physically possible mass flow required for this, which leads to considerable economic and energy-related advantages.

Our innovation relates firstly to the dry expansion system (6) (1), to the dry expansion system (6) (1) with a downstream IHE (2) (internal heat exchanger, that is to say with a heat exchange between the refrigerant liquid line upstream of the expansion valve on the one hand and the suction vapor downstream of the evaporator on the other hand), to the two-stage evaporation system (6) (1 + 2) (a combination of dry expansion system and thermosyphon system, evaporator with IHE) and to further refrigerating installations constructed on this basis.

Depending on operating conditions, relatively great temperature fluctuations on the refrigerant side, upstream of the injection valve (6) (A) and upstream of the condenser (5) (B), are typical of these systems.

These temperatures of the refrigerant (upstream of the injection valve (A) and upstream of the condenser (B)) are at present not kept constant or exactly controlled.

Often only the high or suction pressure (Pc/Po) is controlled and/or kept constant, if that.

This leads to more or less great fluctuations and feedback effects (hunting) of the refrigerating system, and consequently to losses in efficiency and unstable control loops.

The main factors for these fluctuations are on the one hand the changed x value of the refrigerant state in the injection valve (6) and in the beginning of the evaporator (1), that is changed with the changed temperature of the refrigerant (A) (the x value is the value that indicates the proportion of already evaporated refrigerant at the beginning of the evaporation process), which has effects on the performance of the injection valve (6) and the evaporator (1) and on the control response of the injection valve (6) and its performance, or the delivered mass flow of refrigerant and on the other hand the suction vapor at the inlet into the condenser (5), where the changed temperature (B), because of the specific volume assigned to the respective temperature (and pressure), has an influence on the volumetric delivery of the condenser (5), that is in turn the delivered mass flow.

These mass flows, constantly changing as a result of temperature changes, introduce greater or lesser

disturbing factors into the control loop of the refrigerating installation, which lead to fluctuations in the process, and consequently to reductions in performance.

Detailed summary of the invention:

The objective of the invention is to achieve the following in the case of cooling/freezing installations, refrigerating machines for cooling and heating operation, refrigerating installations, refrigerating units, heat pumps and all installations that use refrigerants and refrigerating media:

Stable operation of the installation by:

"Firstly, the temperature of the refrigerant upstream of the injection valve (6) (A) being kept constantly at a defined temperature value (A)."

"Secondly, the temperature of the refrigerant upstream of the condenser (5) (B) being kept at a defined temperature value (B).

"Thirdly, these two measures being used on their own or in combination with each other."

"Fourthly, these three measures leading to the objective in combination with a dry expansion valve control (6) conventionally on the basis of MSS (minimal stable signal) (P8/T22) with or without IHE (internal heat exchanger) (2) measured downstream of the evaporator (1) (T22/P8) or downstream of the IHE (2) (T23/P9) or with the temperature (pressure difference measurement) between the liquid line upstream of the injection valve (6) (T20) and pressure or temperature measurement downstream of the injection valve (6) (P7) (T21) the evaporator (1) (P8) (T22) or the IHE (2) (P9) (T23), the so-called two-stage evaporator control

(T20/P7) (T20/P8) or (T20/P9) or with new expansion valve controls on the basis of the pressure difference (7) over the evaporator (1), the IHE (2), the evaporator and the IHE (1 + 2) or a corresponding reference variable (for example accumulator), or leading to the objective individually.

These measures such as keeping the temperature of the refrigerant liquid upstream of the injection valve constant, keeping the temperature of the suction vapor upstream of the condenser constant, two-stage evaporator process (with corresponding control) and/or pressure difference/level control of the injection valve lead to stable operation of the refrigerating installations (even with great changes in output) on their own or in any desired combination.

If a two-stage evaporator (1 + 2) is used here, minimal temperature differences between the medium to be cooled on the one hand (C/D) and the evaporation temperature to (suction pressure) on the other hand can be additionally achieved.

This temperature difference may in any event be less than if the refrigerant leaves the evaporator (1) "superheated" (P8/T22) in dry expansion operation.

What is novel about our invention is that the temperature of the liquid refrigerant upstream of the injection valve is kept constantly at a predetermined value (A).

It can be kept constant in this way by various measures. For the sake of simplicity, we describe keeping it constant by means of a heat exchanger (4) in the refrigerant liquid line upstream of the injection valve, which keeps the outlet temperature of the liquid refrigerant constant by a second medium. The medium

used for keeping the refrigerant liquid temperature constant may in this case be of any kind desired (gaseous, liquid, etc.).

One possibility for keeping the refrigerant liquid temperature upstream of the injection valve (A) constant may be that the flow (D) of the medium to be cooled, for example water, brine, etc., is passed through a heat exchanger (4), in which the refrigerant is conducted in either co-current, cross-current or counter-current flow, etc., on the second side of the heat exchanger.

Other possibilities for stabilizing the refrigerant liquid temperature upstream of the injection valve (A) may also take place for example by means of stores, latent stores, masses of inertia or storage masses (13) or further measures.

The refrigerant liquid temperature upstream of the injection valve (A) may also be controlled by means of mass flow control of the refrigerant liquid (9) through the IHE (2) or of the suction vapor (12) through the IHE (2) (depending on conditions, sometimes only partial mass flows flow through the IHE (2)).

What is novel about the invention is that the refrigerant liquid temperature upstream of the injection valve (6) (A) is kept constant.

What is novel about the invention is that the refrigerant liquid temperature, especially in the case of the two-stage evaporation process (1 + 2), upstream of the injection valve (6) (A) is kept constant at a very low value, close to or on the left-hand limiting curve of the log (p), h diagram for refrigerants, (the refrigerant therefore enters the evaporator (1) in

liquid form as in the case of a thermosyphon system or with minimal vapor content).

What is novel about the invention is that the refrigerant suction vapor at the inlet into the condenser (5) (B) is kept constant.

Measures for this may be analogous to keeping the refrigerant liquid upstream of the injection valve (6) (A) constant:

Therefore, heat exchangers or storage masses or masses of inertia are used for keeping the suction vapor temperature constant.

Furthermore, there are refrigerating systems with inserted IHEs (2) (two-stage evaporators, semi-flooded systems) which supercool the liquid refrigerant upstream of the injection valve (A) (and the measures for keeping the temperature constant) and superheat (B) the suction vapor downstream of the evaporator (1) (2).

Keeping the suction vapor temperature constant may also be performed by means of measures such as external supercoolers (3), which control the refrigerant liquid inlet temperature into the IHE (2) (8) and in this way control the suction vapor temperature from the IHE (2) (B).

Keeping the suction vapor temperature constant may also be controlled by means of mass flow control of the refrigerant liquid (9) through the IHE (2) or of the suction vapor (12) through the IHE (2).

Keeping the suction vapor temperature constant may also be achieved by greater or lesser "flooding" of the IHE (2) (only in the two-stage evaporation process).

The "flooding" of the IHE (2) may in this case take place by means of a temperature control of the suction vapor at the inlet of the condenser (two-stage evaporator control) (T23), level control (7) directly by the evaporator (1), IHEs (2) individually or together or by means of a reference variable such as for example the accumulator or other or a pressure difference control (7) directly by the evaporator (1) IHEs (2) individually or together.

All these described measures may be used individually or combined in any way desired.

The invention is substantially based on keeping the refrigerant liquid temperature upstream of the injection valve (A) and the suction vapor temperature upstream of the condenser (B) constantly at any desired value (within the limits of what is physically possible but as and when required up to the physical limits) by suitable measures.

The constant temperature of the refrigerant at these two points in the refrigerating system (refrigerant liquid upstream of the injection valve (A), suction vapor upstream of the condenser (B)) achieves the effect of stable operation and, if desired, minimal temperature differences between the media to be cooled (inlet/outlet temperature (C/D) on the one hand and inlet and/or outlet temperature in relation to the evaporation temperature (C/D in relation to to) on the other hand).

Enumeration of the drawings:

- Figure 1: possible solutions for monitoring the refrigerant temperatures upstream of the injection valve and condenser.
- Figure 2: possible solutions for monitoring the refrigerant temperatures upstream of the injection

valve and condenser without auxiliary pumps in the secondary circuit.

- Figure 3: possible solutions for monitoring the refrigerant temperatures upstream of the injection valve and condenser in dry expansion operation without IHE.
- Figure 4: possible solutions for monitoring the refrigerant temperatures upstream of the injection valve and condenser in dry expansion operation with IHE and/or two-stage evaporation.
- Figure 5: possible solutions for monitoring the refrigerant temperatures upstream of the injection valve and condenser in dry expansion operation with IHE and/or two-stage evaporation with external supercooler.
- Figure 6: possible solutions for monitoring the refrigerant temperatures upstream of the injection valve and condenser in dry expansion operation with IHE and/or two-stage evaporation with external supercooler and storage mass or mass of inertia for keeping constant the temperature of the refrigerant upstream of the injection valve instead of the heat exchanger.
- Figure 7: log (p), h diagram.

The diagrams explain the sense and make no claim to be exhaustive. The valves, heat exchangers, etc. may be used individually or combined in every possible form. No further illustrations are provided and reference is made to the text.

Implementation of the invention:

The invention is based on achieving stable operation of refrigerating installations with small temperature differences of the media to be cooled, and consequently higher efficiencies (and thereby highly efficient evaporation in refrigerating installations).

The method of producing cold conditions is supplemented or modified to the novel extent that, in addition to the monitored suction and high pressures in refrigerating systems, the temperature of the liquid refrigerant upstream of the injection valve (A) and of the suction vapor upstream of the condenser inlet (B) is monitored, controlled and kept constant.

Monitoring the refrigerant temperature upstream of the injection valve (A) has the effect of producing defined states in the refrigerant mixture (liquid/vapor). These defined states in the refrigerant lead to stable conditions in the refrigerating circuit.

We obtain the same effect by monitoring the temperature and keeping constant the suction vapor temperature at the condenser inlet (B).

By stabilizing these two temperatures and the associated respective states of the respective refrigerant at these two points in the refrigerating circuit, we achieve stable conditions and prevent feedback effects in the control equipment and hunting of the system, and consequently less disturbances, which leads to a stable control loop and consequently to stable operation of the refrigerating installations and consequently to highly efficient evaporation.

The more stable operation obtained has the effect of producing energy and cost savings and making it possible to operate processes with much smaller temperature differences of the media to be cooled in relation to the respective evaporation temperatures, especially in combination with the two-stage evaporation technique (1 + 2).

As a result, processes can be operated in a simple and low-cost manner that is not possible at present in this way.

These two temperatures (A + B) and the associated refrigerant states can be monitored and stabilized in many possible ways.

The enumeration of possibilities is analogously restricted in this patent specification to just a few.

The innovation is the monitoring of the two described refrigerant states (A + B), irrespective of the method by which this is achieved, only one or the other measure (A or B or 7) having to be taken, depending on the application. It is consequently possible to arrive at the desired result just by the monitoring of the temperature of the liquid refrigerant upstream of the injection valve (A) or the monitoring of the temperature of the suction vapor upstream of the condenser (B) or by the monitoring of the liquid refrigerant upstream of the injection valve and the monitoring of the temperature of the suction vapor (A + B).

Suitable measures for monitoring the temperature of the refrigerant upstream of the injection valve are:

1. Keeping the temperature of the refrigerant upstream of the injection valve constant by using a secondary medium by means of a heat exchanger (4).

2. Keeping the temperature of the liquid refrigerant upstream of the injection valve constant (slow to react) by using a mass (13) (liquid, solid, gaseous or mixed between these states of aggregation).

3. Keeping the temperature of the liquid refrigerant upstream of the injection valve constant, especially when using an IHE or applying the two-stage evaporation process, by means of use of a control valve (9). This control passes only a specific mass flow through the IHE or the second stage of the two-stage evaporation and the remaining mass flow (E) directly or indirectly to the injection valve, it being possible for the mass flow (E) that is made to pass the IHE or the second stage of the two-stage evaporation to be cooled, heated or kept the same.

Suitable measures for monitoring the temperature of the refrigerant upstream of the condenser are:

4. Keeping the temperature of the suction vapor upstream of the condenser (B) constant by using a secondary medium by means of a heat exchange.

5. Keeping the temperature of the suction vapor upstream of the condenser constant (slow to react) by using a mass (liquid, solid, gaseous or mixed between these states of aggregation).

6. Keeping the temperature of the suction vapor upstream of the condenser constant, especially when using an IHE or applying the two-stage evaporation process, by means of use of a control valve (8), (12) and/or (9). This control (12) (9) passes only a specific mass flow through the IHE (2) or the second stage of the two-stage evaporation and the remaining mass flow (9) directly or indirectly to the injection valve (6) or condenser (5).

7. By means of a monitored inlet temperature (8) (F) of the liquid refrigerant into the IHE (2) or the second stage of the two-stage evaporator, for

example using an external refrigerant liquid supercooler (3) or the like.

8. By means of a monitored filling level of the refrigerant to be liquefied in the evaporator or in the IHE or in the second stage of the two-stage evaporator, for example by means of level control (7) or pressure difference measurement (7) or suction vapor temperature control (T23) upstream of the condenser, it being possible for the level control to take place by means of the evaporator, the IHE or the second stage of the two-stage evaporator individually and/or the evaporator alone or in combination with the IHE or the second stage of the two-stage evaporator or a reference object, for example an accumulator.

9. Especially in the case of a refrigerating system with two-stage evaporation (1 + 2), the control and incorporation can be performed as follows (combinations and variants thereof are also possible): injection valve control by means of detecting the temperature of the refrigerant upstream of the injection valve (T20) and pressure/temperature downstream of the injection valve (T21/P7), between the first and the second evaporator stages (P8/T22) or downstream of the second evaporator stage (P9/T23) or combinations thereof. The temperature/pressure difference (T20/P7, P8, P9) serves as a controlled variable for the injection valve (6). A suction vapor temperature detection (T23) upstream of the condenser (5) overrides the temperature difference/pressure control (T20/P7, P8, P9) as and when required. As an alternative to the temperature difference/pressure control, a level or pressure difference control (7) for the injection valve may be used.

The temperature upstream of the injection valve is kept constant by means of suitable measures (as described above). Keeping the temperature of the liquid refrigerant upstream of the injection valve constant in this way may take place for example by using a heat exchanger (4) fitted between the liquid line and the medium flow.

A partial mass flow or the entire mass flow of the cooled medium is conducted (10/11) through the heat exchanger (4) in co-current, counter-current or cross-current flow, etc., in relation to the refrigerant liquid.

The medium may in this case be conducted through the exchanger with a controlled or uncontrolled temperature.

The correct dimensioning of the heat exchanger (4) has the effect that the refrigerant liquid upstream of the injection valve (A) is supercooled or kept constant at any desired temperature level, or if desired even at a very low temperature level, which means that the evaporator (1) is fed with liquid refrigerant or only a small proportion of already evaporated refrigerant.

The proportion of already evaporated refrigerant in the evaporator can be optimized and set to the evaporator type (1), and consequently to the efficiency for starting the evaporation process, with a corresponding temperature of the liquid refrigerant upstream of the injection valve (A).

As an alternative to overriding the injection valve control by the suction gas temperature by flooding the second stage of the two-stage evaporator in the case of excessive suction vapor temperatures upstream of the

condenser (T23), the refrigerant liquid inlet temperature into the second evaporator stage (IHE) (2) (F) may be limited for example by means of an external supercooler (32) in cases of high condensation temperatures.

As an alternative or in combination with this limitation, part of the refrigerant liquid mass flow (E) may be conducted past the second condenser stage (IHE) (2), in dependence on the suction vapor temperature (B).